Estimating larger carnivore numbers from track counts and measurements

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Abstract

Knowing the abundance of larger carnivores is critical for their conservation management. However, direct assessment of carnivore numbers is often difficult, expensive and time-consuming, leaving indirect sampling as a valid and feasible alternative. Indirect census techniques have proved to be cost-effective, repeatable and objective. We therefore estimated the numbers of six larger carnivore species in a relatively small area in northern South Africa, comparing three indirect sampling methods based on track counts and measurements: (i) a qualitative approach, whereby individuals were subjectively identified by comparing differences in track measurements; (ii) a quantitative approach using the strong linear correlation of track density with carnivore density found in other studies; and (iii) a quantitative approach applying repeated measures analysis of variance and post-tests to the track measurement data, in order to test statistically for differences in track sets. All three methods provided similar results that appear to be reasonable and which might be an indication of the real number of larger carnivores that occur in the study area. These results support the reliability of indirect estimates of larger carnivore numbers based on tracking data, which is promising for future research and conservation efforts involving these animals.

Key words: abundance, carnivores, census, count, spoor, tracking

Résumé

Avoir conscience de l'abondance des grands carnivores est très important pour la gestion de leur conservation. Cependant, l'évaluation directe des nombres de carnivores est souvent difficile, nècessitant beaucoup d'argent et de temps, ce qui importe que l'échantillonnage indirect est une alternative fiable et valable. Les techniques de recensement à distance se sont montrèes économiques, renouvelables, et objectives. Nous avons donc estimé le nombre de grands carnivores de six espèces dans une superficie assez petite au nord de l'Afrique du Sud, en comparant trois méthodes d'échantillonnage basèes sur des décomptes des traces et mesures: (i) une approche qualitative, où les individus furent identifiés de manière subjective en étudiant les différences dans les mesures des traces; (ii) une approche quantitative qui se sert de la forte corrélation linéaire de la densité des traces à la densité des carnivores démontrée dans d'autres études; et (iii) une approche quantitative qui impliquent des analyses répétées de la variance et des post-enquêtes sur les mesures des traces afin de disposer des données statistiques pour identifier les différences entre des services des traces. Les trois méthodes fournirent des résultats comparables qui semblent raisonnables et qui peuvent être une bonne indication du vrai nombre de grands carnivores dans la zone de l'étude. Les rèsultats étayent la fiabilité des estimations indirectes de l'abondance de grands carnivores basés sur les données des traces, et sont prometteurs pour des futures recherches et pour la conservation de ces animaux.

Introduction

In all wildlife management and conservation projects, reliable population size estimates are of crucial importance. A number of methods have been developed to determine the abundance of larger carnivores, which is usually a challenging process (Bertram, 1979; Gros, Kelly & Caro, 1996; Mills, 1997; Gese, 2001; Wilson & Delahay, 2001). Among these methods, the direct assessment of carnivore numbers is a particularly difficult, expensive and

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time-consuming procedure. Therefore, several indirect census techniques have been proposed, which have proved to be cost-effective, repeatable and objective (e.g. Van Dyke, Brocke & Shaw, 1986; Van Sickle & Lindzey, 1991; Smallwood & Fitzhugh, 1993, 1995; Beier & Cunningham, 1996; Stander, 1998; Grigione *et al.*, 1999; Lewison, Fitzhugh & Galentine, 2001). All of these sampling methods involve the counting and/or measuring of tracks of the target animals on suitable substrate.

Indirect sampling occurs mostly in areas where direct measures are not possible because of financial or practical constraints, and is thus more efficient than direct sampling when it provides comparable information at a lower cost. Each situation should thus be assessed on its own merits, and the method employed should depend on the objectives, the species, the area and habitat to be surveyed, as well as on the amount of money and time available (Mills, 1997; Wilson & Delahay, 2001).

Smallwood & Fitzhugh (1993) developed a quantitative method of identifying the tracks of individual cougars (*Puma concolor*) by taking measurements from acetate tracings and applying multiple-group discriminant analysis (also see Grigione *et al.*, 1999; Lewison *et al.*, 2001). Stander (1998) described another quantitative technique and showed the validity of track counts as a means of measuring the population densities of large carnivores in Namibia by comparing results from track counts with those from radio-tracking studies. In this study, the track density of leopards (*Panthera pardus*), lions (*Panthera leo*) and African wild dogs (*Lycaon pictus*) showed a strong linear correlation with true density. A similar linear correlation was found by Van Dyke *et al.* (1986) for cougars in the USA.

However, there is a general lack in understanding the results of indirect sampling in terms of accuracy and precision, and it has been suggested that several independent surveys should be conducted in order to arrive at a reliable figure (Gros *et al.*, 1996; Mills, 1997; Wilson & Delahay, 2001). The purpose of the present study was to respond to this need by comparing three indirect counting methods for six larger carnivore species based on track counts and measurements.

Study site and methods

The area selected for this study was the Shayamanzi Game Ranch (SGR; 1500 ha), which is located in the Waterberg region of the Limpopo Province of South Africa, a relatively large ecosystem where carnivores can move between mainly private properties (Grimbeek, 1992). The vegetation is sour bushveld (Acocks, 1988) or Waterberg moist mountain bushveld (Van Rooyen & Bredenkamp, 1998) of the savannah biome. The study was part of a general survey of larger carnivores in an area where direct assessment of ecological parameters, such as feeding habits (Burgener & Gusset, 2003) and carnivore numbers (this study), was not possible for practical and financial reasons, leaving indirect sampling as a valid and feasible alternative.

All the available fresh tracks of the members of the cat (Felidae), hyaena (Hyaenidae) and dog (Canidae) families were recorded periodically over a time span of 6 months in 2001, using the field guide of Stuart & Stuart (1998). Tracks were mainly located on sand roads throughout the study area because this was the only substrate that allowed the identification and measurement of tracks, and because larger carnivores often travel along roads (Mills, 1997; Wilson & Delahay, 2001). The tracking surfaces were not prepared prior to surveying because this would have increased the time spent in the field considerably and because the benefits to be had from such procedures are minor (Smallwood & Fitzhugh, 1995). The measurements were always taken by the same person, and the following points were noted for each set of tracks: location as a grid reference, total length, total width and main pad height of both the front and hind feet (in mm), straddle distance and stride length (in cm). Tracking conditions were not assessed and some unknown degree of dependency was inevitable among the track measurements, simply because most measurements correlate with foot size. The following three methods of analysis were then applied to the tracking data:

(1) A qualitative approach, whereby individuals were identified subjectively by comparing the differences in track measurements and their numbers summed up per larger carnivore species. This was done prior to the quantitative analyses.

(2) The quantitative method of Stander (1998), who assessed the relationship between true density (leopards per 100 km^2, based on radio-tracking data) and track density (leopard tracks found per 100 km road) by a separation of true density and track frequency data from individually known leopards. Stander found that track density (y) showed a strongly significant linear relationship with true density (x), and a simple regression equation of the form $y = ax + b$ resulted in a slope $a = 1.9$ and an intercept $b = 0$. This method, however, was only

applicable to leopards because the slope (*a*) of the regression equation is species dependent (Stander, 1998). Furthermore, as the leopard density in Stander's study area in Namibia was 1.3 times lower than in the area in the Waterberg of South Africa that was covered by the present study (Grimbeek, 1992; determined from radio-tracking data) (1.45 versus 1.89 leopards per 100 km^2 respectively), the result of the above regression equation for the present study was multiplied by 1.3 to allow for the higher leopard density expected.

(3) A quantitative method applying analysis of variance (ANOVA) to the track measurement data was used to test statistically for differences in complete track sets. Track sets were considered to be significantly different from each other at $P < 0.05$. A repeated measures ANOVA was used to increase the power of the test, as the track sets of all larger carnivore species showed a significant effective matching ($P < 0.05$). As post-test in significantly different track sets, the Tukey–Kramer multiple comparisons test was applied, using InStat V2.04 (GraphPad Software, Inc., San Diego, CA, USA, 1993). The number of significantly different track sets identified in the post-tests at $P < 0.05$ was then summed up per larger carnivore species. Although stride length and straddle distance may improve discrimination when track measurements are similar, these variables were excluded from the analysis because they may vary considerably with terrain slope and the behaviour of the animal (Smallwood & Fitzhugh, 1993; Stander *et al.*, 1997).

Results

A total of 283 tracks of six larger carnivore species were located and identified in the study area: leopard, caracal (*Caracal caracal*), serval (*Leptailurus serval*), African wildcat (*Felis silvestris libyca*), brown hyaena (*Parahyaena brunnea*) and black-backed jackal (*Canis mesomelas*). Of these tracks, it was possible to measure 138 (Table 1). Tracks of all the larger carnivores present were found throughout the whole study period and all over the study area.

The results of the indirect estimates of larger carnivore numbers are indicated in Table 2. By comparing differences in track measurements, it was subjectively estimated that the leopard tracks originate from four different individuals. Using the same qualitative procedure, estimates for the other larger carnivore species were also obtained (Table 2), taking into account the difficulties that arose because of different substrate conditions and slopes on which the tracks were measured, and difficulties because of incomplete (caracal and African wildcat) or large (caracal, brown hyaena and black-backed jackal) data sets. Incomplete data sets for caracal and African wildcat resulted from the walking habits of these cats, which often place their hind feet exactly over their front feet, thereby leaving measurable tracks only of the former, as also reported by Stuart & Stuart (1998).

Using the regression method for leopards, the estimated total sample of 300 km sand road from car odometer readings resulted in a track density of 4.7 leopard tracks per 100 km, resulting in turn in a leopard density per 100 km^2 as indicated in Table 2. The repeated measures ANOVA resulted in significantly different track sets in all larger carnivore species, and the post-tests therefore made it possible to distinguish individual track sets (Table 2) (leopard: $n = 10$, $F = 6.866$, $P < 0.0001$; caracal: $n = 32$, $F = 3.901$, $P < 0.0001$; serval: $n = 9$, $F = 6.438$, $P < 0.0001$; African wildcat: $n = 16$, $F = 2.884$, $P =$

Table 1 Track measurements of the larger carnivores on Shayamanzi Game Ranch (mean ± SD)

Species	Total length of front feet (mm)	Total width of front feet (mm)	Main pad height of front feet (mm)	Total length of hind feet (mm)	Total width of hind feet (mm)	Main pad height of hind feet (mm)	Straddle distance (cm)	Stride length (cm)
Leopard (*Panthera pardus*) (n = 10)	87 ± 12	86 ± 13	42 ± 5	84 ± 8	78 ± 5	39 ± 6	4 ± 3	107 ± 16
Caracal (*Caracal caracal*) (n = 32)	47 ± 3	47 ± 6	23 ± 3	46 ± 4	42 ± 3	22 ± 3	1 ± 2	68 ± 16
Serval (*Leptailurus serval*) (n = 9)	47 ± 3	52 ± 3	24 ± 2	46 ± 4	45 ± 5	23 ± 2	1 ± 1	65 ± 9
African wildcat (*Felis silvestris libyca*) (n = 16)	37 ± 2	36 ± 3	16 ± 1	32 ± 5	31 ± 5	15 ± 1	0 ± 0	47 ± 11
Brown hyaena (*Parahyaena brunnea*) (n = 49)	96 ± 10	86 ± 7	45 ± 6	74 ± 8	65 ± 5	34 ± 4	6 ± 3	123 ± 27
Black-backed jackal (*Canis mesomelas*) (n = 22)	55 ± 5	45 ± 3	22 ± 2	50 ± 4	39 ± 4	18 ± 2	3 ± 2	86 ± 21

Table 2 Estimates of the number of larger carnivores on Shayamanzi Game Ranch, using three qualitative and quantitative indirect sampling methods based on track counts and measurements (described in the text)

Species	Qualitative estimate	Quantitative estimates: Regression method	Quantitative estimates: ANOVA method
Leopard (*Panthera pardus*)	4	3.2	3
Caracal (*Caracal caracal*)	6	–	5
Serval (*Leptailurus serval*)	3	–	3
African wildcat (*Felis silvestris libyca*)	5	–	5
Brown hyaena (*Parahyaena brunnea*)	13	–	12
Black-backed jackal (*Canis mesomelas*)	10	–	7

0.0490; brown hyaena: n = 49, $F = 11.248$, $P < 0.0001$; black-backed jackal: n = 22, $F = 6.852$, $P < 0.0001$).

Discussion

All the larger carnivore species that might be expected to occur in the area and habitat did so (Skinner & Smithers, 1990). From an ecological viewpoint, this is an indication of good habitat conditions for larger carnivores in this region. The occurrence of brown hyaena must be pointed out in particular, as these animals, with their role as scavengers (Burgener & Gusset, 2003), are an integral part of an ecosystem. The track measurements (Table 1) are in accordance with the measurements reported by Stuart & Stuart (1998). The locations where tracks of larger carnivores were found indicate that these animals occur all over the study site. Furthermore, the fact that tracks of all larger carnivore species were found throughout the whole study period indicates that these animals occur on SGR for all or at least most of the time.

It was not possible to conclusively evaluate the reliability of the indirect estimates of larger carnivore numbers (Table 2) as no direct census could be conducted because of financial and practical constraints, a major drawback of this study. Other limitations of the study were small sample sizes and the small size of the study area as such, with ranging patterns of all of the larger carnivore species present potentially exceeding the size of SGR (Skinner & Smithers, 1990). However, considering their social and spatial organization (Skinner & Smithers, 1990), all estimates appear to be reasonable and might be an indication of the real number of larger carnivores that occur in or pass through the study area, also because a comparison between the three methods of estimating numbers in leopards shows that all of them gave us similar results (Table 2). The estimated leopard density in our study was considerably higher than in Grimbeek's (1992) study (3.2 versus 1.9 leopards per 100 km^2 respectively), possibly because of recently decreased persecution pressure and increased prey availability as a consequence of game ranching for tourism and hunting, or due to methodological differences (estimates derived from track counts on roads and from radio-tracking data, respectively; also see Smallwood & Schonewald, 1998).

The advantage of the method of Stander (1998) is that the tracks do not have to be measured but only counted, which is less time consuming, given that the complete measuring process of one track set took about 10 min. Stander's approach therefore appears to be promising for future research, and more studies using this procedure should be conducted, in order to validate the indirect sampling methods against direct counts and to develop regression equations for more of the species present in different habitats. Furthermore, the correction factor introduced into the regression equation to account for the different leopard densities seems to be appropriate, as concluded from a comparison between the result of the regression method with the results of the other two methods (Table 2). One drawback of Stander's method, however, is that individuals cannot be identified, unless experienced local trackers who can distinguish between individual tracks without measuring them are available.

Furthermore, even a qualitative approach that subjectively discriminates individuals from track measurement differences appears to be fairly accurate, although most qualitative estimates were larger than the estimates derived from the quantitative methods (Table 2). This is not in accordance with the experience of Smallwood & Fitzhugh (1993), who stated that a qualitative approach to track discrimination does not usually work (but see Stander *et al.*, 1997). Whatever method is used in future research, be it qualitative or quantitative, the substrate condition and slope where tracks were measured should also be recorded for a better discrimination of tracks.

Overall, the results of this comparative study suggest that tracking data relating to the target species can indeed provide a reliable and cost-effective indirect estimate of larger carnivore numbers, which is promising for future research and conservation efforts involving these animals.

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